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viewpoint

The code, the text and the language of God

When explaining science and its implications to the lay public, metaphors come in handy. But their indiscriminate use could also easily backfire

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Communication between scientists about their work is filled with images. This is inevitable when it comes to explaining complex ideas and concepts that are not directly observable, such as the subatomic particles that comprise a proton or an electron, or the processes inside a cell that lead to the correct formation of a protein. When new discoveries are made, the words to describe them are usually lacking and must be borrowed from the physical world or common speech: lipid rafts, chaperones, molecular markers. When scientists try to explain their findings to the public, or when the media try to make science more palatable to their readers or viewers, these metaphors become even more colourful: cells are factories, proteins carry zip codes, mitochondria are the powerhouse of the cell, and cells of the immune system go to school. As Harold Varmus said, "There's a metaphor contest going on" (Angier, 2000).

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Devising metaphors to explain complex concepts is a creative process and it reveals how scientists think and how ideas about a world too small to grasp are represented in their mind (Brown, 2003). However, metaphors, when carried too far, can convey a confusing or even misleading message to the public. They accentuate certain aspects of the subject or process they are depicting, while neglecting others. Sometimes they even awake associations not intended by the author, when molecules suddenly acquire a personality of their own or are endowed with human goal-directed behaviour—take, for example, a molecule that 'finds' a partner or a cell that takes a developmental 'decision', such as committing 'cell suicide'. Using molecular genetics as an example, I will try to follow some of biology's metaphors from their origin in scientific communication into the real world and analyse their impact on the public perception of science.

Common language talks about DNA as 'information' or 'a code'. For a very long time, scientists suspected that something—some kind of plan, specificity or driving force—resided within the sperm and/or egg, such that a snake developed from a snake egg and humans created human offspring. But it was only in the late 1940s and 1950s, when cyberneticists, physicists and mathematicians entered the field of molecular biology, that scientists came to interpret this 'something' as information. The physicist Erwin Schrödinger probably coined the term 'code' when he described living organisms in terms of their molecular and atomic structure, in his influential book *What is Life* (Schrödinger, 1944). The complete pattern of the future development of an organism and its function when mature, Schrödinger wrote, is contained in the chromosomes in the form of a 'code'. His writings had a strong influence on both Francis Crick and James Watson and their later discovery of the structure of DNA. "Schrödinger probably wasn't the first, but he was the first one I'd read to say that there must be a code of some kind that allowed molecules in cells to carry information," Watson said in an interview with *Scientific American* (Watson, 2003). Indeed, Watson and Crick, in a paper on the implications of their DNA structure, picked up Schrödinger's metaphor when they wrote that "it therefore seems likely that the precise sequence of the bases is the code which carries the genetical information." From today's perspective it seems rather inevitable that, when people started to think about the molecular basis of inheritance, they came up with these analogies. Although the metaphors seem so intuitive that it is hard for a geneticist to picture DNA as anything other than a code that transmits information, in her book *Who Wrote the Book of Life*, Lily E. Kay doubted that it is a natural property of DNA to be thought of as informational (Kay, 2000).

When H. Gobind Khorana, Marshall W. Nirenberg and other scientists revealed the trinucleotide code and the correlation between nucleic acids and proteins, this was referred to as 'decoding' or 'deciphering' the code. These metaphors have gained momentum and are now routinely used to describe the sequencing of the human genome. For the scientists involved, these references are clear by context—whether the issue is the DNA sequence itself or the relationship between DNA and protein. But news headlines such as "Decoding the book of life", "Cracking the code of life" or "Breaking the code of life", when referring to the sequencing of the human genome, are misleading to the layperson because they imply that the decoded text can be read like a novel. No scientist would dispute that this is far from the current state of the art. Understanding the message hidden in the 3 billion base pairs of the human genome would require a detailed translation of its sequence into physiological function. DNA itself is a "text without context" (Nelkin, 2001). Indeed, genes by themselves barely do anything. Genes just describe how to

make proteins, or cease to make them, or regulate their production as directed by other proteins. Not even the basics of protein function at the level of protein folding can be deduced from the genes. It is not genes but intricate protein networks that constantly survey the environment outside the cell, monitor metabolic processes and integrate this information into physical function. Simply deciphering the text as laid down in the genome therefore does not necessarily predict how life works at the cellular, let alone at the organismal, level. Nonetheless, 'decoding' metaphors are used by the media and scientists alike, and have even reached industry: The company deCODE Genetics uses the slogan "decoding the language of life" on its corporate website. Through these metaphors, the layperson perceives humankind as demystified, its secrets revealed.

> "And in the Human Genome, Chromosomes Chapter IXX, the Lord speaks to us of His divine plan, saying, 'cgggggggccc ggagcgggat …'"

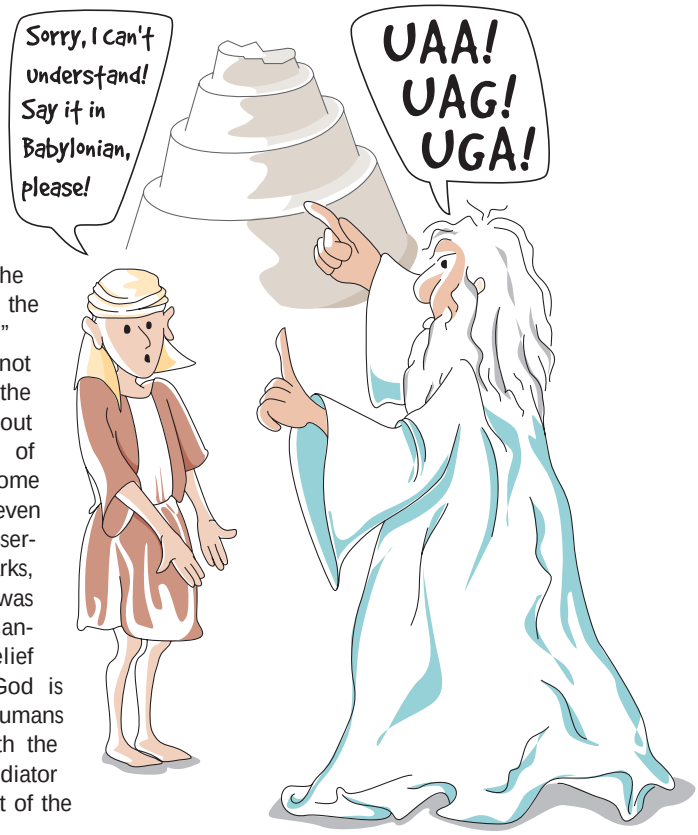
From understanding the genome as a coded message, interpreting it as a text, book or language is not so far-fetched. These metaphors convey an important scientific principle: a sequence of a limited assortment of building blocks, like letters in a text, can carry a message. In his book *The Language of Life,* George Beadle wrote: "… the deciphering of the DNA code has revealed a language … as old as life itself, a language that is the most living language of all" (Beadle & Beadle, 1966). More recently, when scientists celebrated the completion of the first draft of the human genome in 2000, the 'book' and 'language' metaphors were revived—not just reinvented by the press in the service of the public understanding of science, but used by high-ranking scientists involved in the genome project to describe their achievement. On 26 June 2000, when Francis Collins, Director of the National Human Genome Research Institute, announced the completion of the first draft in a major media event at the White House, he said "Today, we celebrate the revelation of the first draft of the human book of life" and declared that this breakthrough lets humans for the first time read "our own instruction book."

But what exactly do scientists mean when they say "book of life"? Collins has several explanations of its content, describing it as "a narrative of the journey of our species through time", "a shop manual", "a detailed blueprint", and "a transformative textbook of medicine." These explanations are confusing. The genome carries information that has developed through evolution and is translated into physiology by cells. Calling it a "narrative" or a "textbook" implies that it is written with intention and is meant to be read by humans. This confusion in intention and target audience misinterprets the role of scientists. Rather than describing them as outside observers trying to untangle the complexity of life, they are displayed as being part of the process, as the ones who are meant to read and interpret the message written down in the genome. But who is the author?

Francis Collins, at the White House event, was quick to give the answer and introduce another player into biological research. He referred to the sequence of the human genome as "our own instruction book, previously known only to God." US President William J. Clinton similarly praised the scientists' work, saying that "today, we are learning the language in which God created life."

At a press conference the following year, Collins carried his reference to God even further: "But we are also profoundly humbled by the privilege of turning the pages that describe the miracle of human life, written in the mysterious language of all the ages, the language of God."

In his remarks, Collins not only further confused the message to the public about the real implications of knowing the human genome sequence, but he might even have done science a disservice. According to his remarks, the text of the genome was written by God, in His language. If we follow this belief further, it implies that God is actually talking to humans through the genome, with the scientist being the mediator between God and the rest of the world. This metaphor definitely does not convey a scientific concept and falsely attributes to scientists a role as priests who read God's instructions and translate and interpret them for the public. This serves neither science nor religion. From a religious point of view, this could very well amount to blasphemy. From science's point of view, it could further damage the role of science, because it introduces some higher being's will and intentions into the scientific exercise, after centuries of attempting to free science and research from the limits imposed by religious leaders. In the best case, it provokes sarcasm: "And in the Human Genome, Chromosomes Chapter IXX, the Lord speaks to us of His divine plan, saying, 'cgggggggccc ggagcgggat…'" (Franks, 2002). In the worst case, it provokes public fear—the idea of the scientists 'playing God' is not too unbelievable. And the public does listen to what the scientists are saying—indeed, public attention to the genome project was unrivalled. In 2000, *The New York Times* alone published 108 articles related to the Human Genome Project. Was it this outburst in media attention that turned scientists into PR spokesmen and encouraged them to blow their speech out of proportion?



It is a common misconception that metaphors are used only when addressing or explaining scientific concepts to the public, whereas communication between scientists is purely objective. Thinking of genes as 'controlling' or 'programming' development—common metaphors used in developmental biology—dictates a certain view of these processes that might not reflect the whole truth, and disguises other aspects. The consequences for this area of research are discussed elsewhere (Nijhout, 1990). The use of metaphors in the public discourse affects public understanding, and eventually public acceptance, of science and technology. In general, there are two levels of metaphor misuse: metaphors blurring the scientific concept they are supposed to clarify, and metaphors that awake unintended associations and mislead public understanding.

> Excessive use of metaphors does little to clarify the science behind them because their explanatory value is not additive

A common symptom of metaphors blurring a scientific concept is their appearance in large numbers and high density. Excessive use of metaphors does little to clarify the science behind them because their explanatory value is not additive. "This map will describe for us the exact content and structure, not only of each and every gene associated with a species, but also the precoded information, or 'chemical spelling' that controls when a particular gene is turned 'on' or 'off'" (Venter & Cohen, 1997). This swamp of verbosity contains four or five metaphors, but it is nonetheless—or rather because of this—hard to grasp. Even someone with a background knowledge of molecular biology will not be able to grasp the sense of this sentence easily and without rereading. It just seems impossible to think of DNA as a map, information (encompassing both content and structure), a code (or rather a precode), a text and a chemical structure, all at the same time. The lay reader is overwhelmed with an impression of impact, meaning, prominence, significance and seriousness, but deprived of any means to understand what exactly has been said. If this is an attempt to further public understanding of biological research, it has failed and could well contribute further to the image of scientists as practitioners who are unable to explain their work in simple and easily understandable terms.

Moreover, the inconsiderate use of metaphors that promote confusion can also lead to misconceptions. Genetic metaphors often convey the impression that there is much more potential or many more implications in genetics and genomics than is really so. This, of course, may be profitable in fundraising, but is counterproductive in conveying credibility or fostering public acceptance. The exaggeration of the potential of molecular genetics is achieved by overemphasizing the power of the gene and also that of the scientist analysing it. Walter Gilbert, Professor in the Department of Molecular and Cellular Biology at Harvard University (Boston, MA, USA), has introduced public lectures by pulling a CD from his pocket and saying, "This is you" (Nelkin, 2001). This is a gross overinterpretation of the genome's role in our development and completely neglects the importance of environmental factors on the formation of the individual. Similarly, "reading, from cover to cover, the first draft of this 'Book of Life'", as Collins put it, is not exactly what scientists are now capable of doing. Rather, they are trying to infer some meaning from small individual chunks of text. The combination of these two powerful metaphors supports the idea that the essence of mankind is a DNA sequence and that scientists are about to disclose it—to read it "from cover to cover". Taken a little bit further, it means that human beings are deprived of all their mysteries and secrets, as their DNA can be analysed and manipulated at the whim of the scientists, who are therefore taking over God's part in human evolution. Indiscriminate use of these metaphors provokes fear and disapproval in the public, which we have already witnessed in the various public debates on prenatal genetic diagnosis, gene patenting, the use of genomic markers to predict predisposition to disease, and the use of DNA to identify individuals. These increasing concerns could in turn encourage scientists to explain their work in even blunter terms, with even more penetrative power, creating more fear and resistance among the public—a vicious circle. This is not to say that scientists should start communicating to the public in purely scientific terms—metaphors have an important role in helping the public to understand and eventually accept science. But they should become more aware of the nature of metaphors and the images they create in the reader's or listener's mind, and should not use them indiscriminately or in an exaggerated way. As our parents used to tell us when we were children: "Watch your language!"

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